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AIR QUALITY ASSESSMENT IN AN OIL AND GAS FIELD AT ATRUSH AREA WITH PARTICULARE REFERENCE TO SULFUR DIOXIDE AND NITROGEN DIOIXDE

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ABSTRACT:

The effectiveness and usability of a diffusion tube for air quality sampling were assessed at 14 sites throughout an oil and gas production area in Atrush sub-district for measurement of Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air by Palmes diffusion tubes in air during autumn and winter season of 2021-2022. Using triethanolamine as a trapping agent, the passive sampler collects SO2 and NO_2, which are then proven to be sulphate and nitrite using ion chromatography and visible spectrometry. Ion chromatography was used to determine the respective dissolved ionic forms of SO_2. Additionally, Ultraviolet-Visible (UV-Vis) spectrophotometry used to analyse NO_2 as nitrite. Sulfur dioxide (SO_2) concentration was high in locations close to flare with high elevation, as well as in winter season were higher than that of autumn season, the highest average of CPF (Central Processing Facility) is (26.39 ppb), however the highest concentration recorded is below Iraqi standard limit 140 ppb for 24 hr and lowest average at ECP3(Entry Check Point 3) (4.37 ppb) respectively. Nitrogen dioxide (NO_2) concentrations were high in locations where heavy equipment's operated and in diesel consumption areas, highest average of NO_2 concentration of E pad (East Pad) is (8.94 ppb), and lowest average was in ECP3 (3.09 ppb).

KEYWORDS: Sulfur Dioxide, Nitrogen Dioxide, Pollution, Air Quality, Diffusion tube.

1. INTRODUCTION

In the most recent decades, pollution of the air has emerged as a significant problem, posing significant risks to both human health as well as the natural environment (Bower et al., 1991). Individual cigarettes, as well as natural occurrences like volcanic activity, as well as large volumes of pollutants created by automobiles and industrial operations, are all examples of pollution sources (Robinson, 2005). A long-term results of the air pollution on the start of illnesses like chest diseases also inflammatory disorders, cardiovascular dysfunctions, also tumour are generally acknowledged (Rumana et al., 2014, Yamamoto et al., 2014). As the direct outcome, air pollution is responsible for the deaths of millions of people all over the world every year (Faustini et al., 2013). A recent study discovered a connection among male infertility with air pollutants (Zhou et al., 2014). Over the last decades, there have been significant improvements in our understanding for the impact of the air pollution on human well-being (Dasgupta and Srikanth, 2020). The majority of society, including those who suffer from lower and upper respiratory issues, is aware that air pollution can induce respiratory difficulties (Bernstein et al., 2004). Particulate matter (PM), Sulfur dioxide, Nitrogen oxide, also Ozone are examples of historical air pollutants that are often utilized as indicators of fuel combustion and transport air pollution. Total suspended particle (TSP) levels in several big cities were quite high in the mid-twentieth century. For instance, during the event that took place in London in 1952, the ambient levels of the TSP as well as SO_2 reached 1000s of micrograms and milligrams per cubic metre (mg/m3) (Davis, 2002). During 1970s, the transboundary nature of air pollutants were already confirmed and recorded, a significant amount of focus has been placed on the reduction of Sulfur dioxide (SO_2) emissions (Menz and Seip, 2004, Simpson et al., 1999). Vestreng (Vestreng et al., 2007) carried out study about Europe's anthropogenic Sulfur emissions has decreased gradually during the past 25 years, from around 55 Tg(total emission trend) SO_2 in 1980 to 15 Tg SO_2 in 2004. When the concentration of SO_2 exceeds the World Health Organization's (WHO) recommended levels, it has a particularly negative impact on persons suffering from asthma, bronchitis, lung and heart disorders (Khan and Siddiqui, 2014). When Sulfur dioxide combines with water, an acid called Sulfuric acid is produced. Sulfuric acid is the primary component of acid rain and a factor in the loss of forest cover (Vestreng et al., 2007). The petroleum sector has a variety of pollution sources, with the following being the major categories of emission sources which include Production emission that the standard process that occurs in the oil and gas, petroleum refining sectors involve separations, transformations, and processes such as fracturing, transforming, polymerization. The gases released after these activities are called as Production emissions, releases from burning are produced by the combustion of energies for processing and transport. The main pollutant that emit from oil and gas production is Sulfur dioxide, which is a colourless soluble aerosol with a distinctive unpleasant odour. It is generated by the burning of Sulfur-containing fossil fuels. Coal and lignite combustion account for around 80% of global emissions, with oil accounting for the remaining 20%. Coal generally contains approximately 2% Sulfur by weight, whereas heavy fuel oil has about 3% (Harrop, 2018). Rapid economic growth and urbanization in worldwide country have resulted in major air pollution concerns in recent decades, with NOx would become the fastest rising air pollutant in some Asian country over the previous two decades (Zhao et al., 2013). Attempts in Europe and North America to minimize anthropogenic NO_2 emissions have resulted in

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remarkable decreases in urban NO_2 levels (Zhou et al., 2012). The aim and objective of this study Were to identify and evaluate the concentration of SO_2 and/or NO_2 pollutant in study area, identify factors affecting dispersion of gases in atmosphere, assessment of pollutant in oil field area and estimated downwind ambient concentration of pollutant emitted in oil field.

2. MATERIAL AND METHOD

2.1 Description of the Study Area

The Study field area is located approximately 90 km north of Erbil and 70km north-northeast of Mosul (36°52'8.00"N, 43°29'2.63"E) . The field is approximately 30km long and 9km wide, covering an area of approximately 270 km2. The terrain within the block is characterised by the high mountain ridge (Chiya E Khere Mountain) which generally follows the high points of the sub-surface reservoir. The elevations of the block vary from approximately 600m to 1600m above mean seal level. The majority of the Upper Jurassic BSAM (Barsarin, Sargelu, Alan and Mus formations) reservoir is located under the slopes of the north side of the ridge, with the majority of populated areas located to the south. Hence the Chiya E Khere mountain ridge effectively screens the majority of activities associated with the development of the Atrush block from much of the local population.

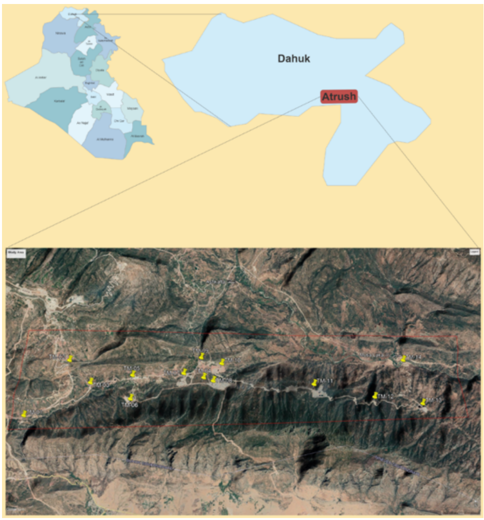

Figure 1: Study Area map (Google map)

2.2 Meteorological Data

The models that are now available predict a moderately to high temperature climate for the lowlands, including an annual precipitation average of around 380 millimetres and temperatures that range from 0.6 to 37.3°C with significant changes caused by atmospheric circulation effects and mountain air circulation patterns(Wilkinson, 2003). While summers are dry and hot to very hot, winters are mild to chilly. About 90% of the yearly precipitation falls between December and March, during the winter season. The climate in the mountainous highlands is categorized as Mediterranean, with up to 1000 mm of precipitation annually and a lengthy rainy season (November to April)(Al-Zuhairi et al., 2016, Eklund and Seaquist, 2015). Majority of rivers and tributaries are active in rainy season (Othman and Gloaguen, 2013) and ephemeral or inactive in the dry season. The Tigris, Great Zab, Nahr al-Khazir and Khabur are perennially active rivers.

2.3 Sample Analysis

Diffusive samplers available in a variety of designs, including radial samplers, badges, and Palmes diffusive samplers. 17–19 The Palmes diffusive sampler(Palmes et al., 1976) provided by Gradko Int. Ltd. was selected in order to concentrate on the most popular diffusional samplers in Europe. With the use of a PTFE teflon membranes and a static layer, the Palmes diffusive sampler may collect air samples from the ambient atmosphere at a pace determined by the tube's diameters and gaseous diffusion (Gerboles et al., 2006).

2.4 Sampling

Diffusion tubes were deployed in 14 locations in different elevation and distance from source of flare for a period of time during hot and cold season between 2021-2022; as just a result, they are constructed in such a way as to ensure that a significant concentration of substances is absorbed onto their surfaces before being noticed during the analysis. The tube Were positioned in the designated location for monitoring, and it was remain there for anywhere among two and four weeks. After the sample period has come to an end, the tubes are sealed and sent back to the lab for further examination. Depending on the type of diffusion tube being examined, a specific method of examination is applied. The lab determined the concentration of each component that is present on the tube. This information is then combined with the absorption rate in a calculation to determine the average concentration of substances that were available in the air during the course of the monitoring period. The data are presented in terms of parts per billion (ppb) and micrograms per cubic meter (µg.m-3) so that they can be compared to the values recommended by health organizations (Singla, 2018).

Table 1: Sampling Locations, Coordinates and Elevation

Location Code	Locations (Area)	Coordinates UTM	Elevation
TM01	D pad Down Area	38n 358484, 4080335	1074 m
TM02	Shilya Road	38n 360008, 4082086	1157 m
TM03	Entry Check Point 1 (ECP1)	38n 360624, 4081378	1064 m
TM04	Waste Water Pit Area	38n 361448, 4081522	1138 m
TM05	ABC Camp (Base camp)	38n 362018, 4081603	1159 m
TM06	A pad	38n 361965, 4080849	1168 m
TM07	ATOC (Main Camp)	38n 363648, 4081663	1060 m
TM08	Central Process Facility (CPF)	38n 364599, 4081416	1120 m
TM09	Entry Check Point 2 (ECP2)	38n 364209, 4082170	1085 m
TM10	G pad	38n 364870, 4081982	1060 m
TM11	E pad	38n 367841, 4081296	1180 m

TM12	Right of Way (ROW)	38n 369804, 4080886	1097 m
TM13	C pad	38n 371379, 4080669	1004 m
TM14	Entry Check Point 3(ECP3)	38n 370907, 4082109	656 m

3. RESULT AND DISCUSSION

3.1 Descriptive Statistics

The mean and standard deviation for SO_2 and NO_2 concentrations for the seasonal cycle September 2021 to March 2022 are presented in Figure 2. Fourteen locations recorded lowest average concentration of SO_2 were 4.37 ppb at ECP3 and the highest average were 26.39 ±3.61 ppb at CPF, while the lowest average of NO_2 were 3.09 ±0.202 ppb and the highest average were 8.94 ± 3.83 ppb at E Pad area. Within a range of 15 percent, which is regarded as a suitable percentile for routine passive monitoring, the passive approach generally agreed with active procedures (Ferm and Svanberg, 1998).

Table 2: Mean and Standard Deviation for SO_2 and NO_2 in 14 different locations for Oil and Gas exploration and production area.

Area	SO2 (ppb)		NO2 (ppb)	
	Mean	Standard Deviation	Mean	Standard Deviation
D pad Down Area	14.51	5.07	6.43	1.12
Shilya Road	20.57	5.98	6.35	2.4
ECP 1	14.81	2.4	6.1	1.55
Wastewater Pit Area	18.58	2.96	5.99	1.85
ABC Camp	16.03	2.75	3.85	1.87
A pad	22.31	3.55	6.31	3.08
ATOC	10.69	2.14	5.06	2.33
CPF	26.39	3.61	5.75	2.58
ECP 2	16.99	6.47	7.72	4.33
G pad	16.3	6.06	7.23	3.46
E pad	23.07	2.69	8.94	3.83
Right of Way (ROW)	13.37	4.34	3.58	1.29
C pad	11.09	4.33	3.1	1.81
ECP 3	4.37	1.65	3.09	3.12

3.1.1 SO_2 concentration in ambient air: Table 2 displays Mean and Standard Deviation for SO_2 and NO_2 pollutants in an oil and gas exploration and production in 14 different area. The highest amount of SO_2 is explored in CPF (Central Process Facility) with 26.39 ppb which is nearest location to the flare with an elevation 1120 m above sea, The greatest SO_2 deposition was seen close to the main stacks that emit SO_2 (Hsu et al., 2016). Islam et.al., studied and observed the maximum SO_2 concentration was observed at one of the site during the 2nd exposure period with a value of 1.91 ppb which located far from flare (Islam et al., 2016), while Mahdi et.al., recorded average of 60 ppb of SO_2 in Duhok city on 2017 (Mahdi et al., 2020) which almost triple of current study due to the sulfur pollution by vehicle exhaust. The maximum permissible value for the concentrations of SO_2 and CO in the northern region of Iraq is 0.14 ppm for 24 hours, however the highest recorded concentration in study area is below Iraqi standard. Followed by E pad 23.07 ppb located east side of flare with an 1180 m above sea as in the similar elevation with CPF which the dispersion of gases and wind direction has impact on the site as well as temporary production facility in operation, A pad 22.31 ppb which located west of flare with 1168 m above sea as almost similar elevation with CPF, Shilya road 20.57 ppb is from north west of flare with elevation 1157 m, Wastewater pit area 18.58 ppb. ECP2 and G pad are 16.99 ppb, 16.30 ppb as the readings are close each other due to close distance to each other where both located north of flare, however both ECP1 14.81 ppb and D pad down area 14.51 ppb are adjacent located far west from flare. Right of way 3.37 ppb and C pad 11.09 ppb which are located far east from flare and nearby each other with huge distance from flare in a complex terrain between them, however ATOC 10.69 ppb is just in down west side of flare as has similar reading with C pad due to similar elevation which might have impact on dispersion of the gases around. Finally ECP3 4.37 ppb is from far east side of flare with low elevation, respectively while the lowest detected by Nazrul Islam was 0.47 ppb (Islam et al., 2016). Respectively the mean of SO_2 and NO_2 for all 14 locations shown in figure 2.

The offshore facilities are where the majority of SO_2 emissions take place. The gas flare was the primary source of SO_2 at the offshore facilities 79.13 percent; sweet gas and a little quantity of sour gas were burned during the water treatment process (Papailias and Mavroidis, 2018).

3.1.2 NO_2 concentration in ambient air: The highest amount of NO_2 is explored in E pad area was 8.94 ppb due to temporary facility operation and diesel used heavy equipment, generators emissions and local timber activities, while study carried out by Islam et.al., and observed similar result with the maximum concentration of NO_2 among all locations exposure period was 9.1 ppb (Islam et al., 2016). Followed by ECP2 7.72 ppb where the entry point and stopping heavy machines as located north side of flare, G pad 7.23 ppb as similar is located north side of flare and adjacent to ECP2 where some drilling activities performed as result of high traffic of heavy equipment and diesel used drilling equipment has impact both locations. (Hashim et al., 2021) studied During the COVID-19 lockdown in Iraq, the effects of emission reductions due to reduced anthropogenic activities, primarily on transportation and industry, on air pollution were investigated. During four periods of partial and total lockdown, the NO2 concentration in Baghdad was reduced by 6, 7, 8, and 20%, respectively. D pad down area 6.43 and Shilya road 6.35 ppb is located far west of flare, however, is on the main road of area which high heavy traffic cause reading of NO_2. (Wu et al., 2021) During the COVID-19 pandemic, the diurnal variation of NO2 and CO was significantly reduced at all Shanghai stations due to vehicular movement restrictions, particularly during peak traffic hours. A pad 6.31 ppb, ECP1 6.10 ppb where the check point of entering of heavy equipment to activity site which cause of NO_2 emission reading. Wastewater pit area 5.99 ppb, CPF 5.75 ppb, ATOC 5.06 ppb, ABC camp 3.85 ppb, Right of way 3.58 ppb, C pad 3.10 ppb, and ECP3 3.09 ppb respectively as shown in figure 2.

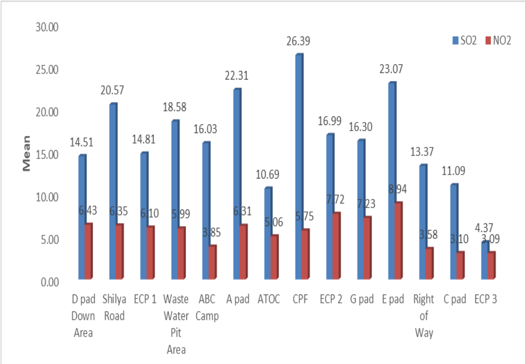

Figure 2: Mean for SO_2 and NO_2 in ppb for Oil and Gas exploration and production in 14 different area.

Table 3: Mean and Standard Deviation for SO_2 and NO_2 for oil and gas exploration and production in seven different months.

Month	SO_2 (ppb)		NO_2 (ppb)	
	Mean	Standard Deviation	Mean	Standard Deviation
Sep-21	15.24	6.69	6.14	3.01
Oct-21	17.49	5.2	6.32	2.46
Nov-21	17.34	7.41	7.21	2.45
Dec-21	15.52	8.19	2.45	2.98
Jan-22	15.59	5.59	6.19	2.62
Feb-22	19.01	8.37	6.42	2.61
Mar-22	14.36	5.11	5.03	2.73

3.1.3 Seasonal Variation: Table 3 shows the mean and standard deviation for SO_2 and NO_2 amounts for oil and gas exploration and production over seven months. The highest amount of SO_2 is explored in February 2022, is 19.01 ppb, while studied carried out in south Iraq and recorded 165 ppb in winter season (Shehabalden and Azeez, 2017). followed by October 2021 17.4 ppb, November 2021 17.34 ppb where previous study recorded 147 ppb in autumn season. Where the level decreased in January 2022 15.59 ppb, December 2021 15.52 ppb due to precipitation of pollutant by effect of rain and snow, as well as the level of SO_2 reduced in September 2021 15.24 ppb, and March 2022 14.36 ppb respectively as shown in figure 3.
Furthermore, the highest amount of NO_2 is explored in November 2021 7.21 ppb, Because the primary sources of SO_2 and NO_2 emissions are industrial and transportation emissions, which only have modest seasonal cycles, these emissions exhibit weak seasonal changes, with ratios of 1.4 and 1.3 between their maxima and minima values(Zhang et al., 2012).
Shehabalden et.al., (2017) recorded NO_2 with a concentration of 185 ppb in autumn season in south Iraq. Followed by February 2022 6.42 ppb, October 2021 6.32 ppb, January 2021 6.19 ppb, September 2021 6.14 ppb, March 2022 5.03 ppb, and December 2021 2.45 ppb, when daytime sunlight is less intense, there is less photodissociation of ozone and less hydroxyl radical production, which results in less conversion of NO_2 to HNO_3(Hertel et al., 2011). Respectively as shown in figure 4. When stated as NO2 equivalent, the total 2014 emissions of nitrogen oxides ($NO_x = NO + NO_2$) and nitrous oxide (N_2O) from offshore and onshore facilities from oil and gas extraction in Greece were 36.53 tonne (Papailias and Mavroidis, 2018).

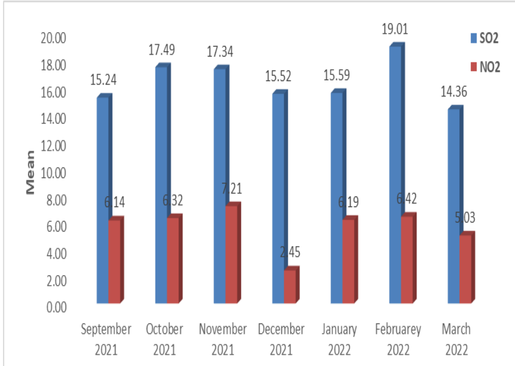

Figure 3: Mean of monthly SO_2 and NO_2 concentration.

3.2 Normality Test

A normality test is used to determine whether a sample data has been drawn from a normally distributed population. Kolmogorov-Smirnov (K-S) test is used for normality of the data if the sample is 50 or more (Aroian et al., 2017). According to the normality test in Table 4, the p-values of both SO_2 (0.200) and NO_2 (0.070) are greater than the significant level of alpha value (0.05) and this indicates that the data sets are normally distributed.

Table 4: Normality Test for SO_2 and NO_2 for Oil and Gas exploration and production

Parameters	Kolmogorov-Smirnova		
	Statistic	df	p-value
SO2	0.063	98	0.2
NO2	0.086	98	0.07

3.3 Test of Homogeneity of Variance

Homogeneity of variance is evaluated using Levene's Test for Equality of Variances. Orderly to meet the statistical expectation of homogeneity of variance, the p-value for Levene's Test should be above 0.05. A p-value less than 0.05 specify a violation of the expectation. If a violation occurs, it is likely that conducting the non-parametric equivalent of the analysis is more appropriate. According to Levene's Test for Equality of Variances from Table 5, p-values for both variables SO_2 (0.319) and NO_2 (0.438) are greater than 0.05 (non-significant), therefore equal variances of the variables are assumed.

Table 5: Homogeneity of Variances Test for SO_2 and NO_2 for oil and gas exploration and production

Gases	Levene Statistic	p-value
SO2	1.166	0.319
NO2	1.023	0.438

Table 6 and 7 shows there are a statistically significant difference between the mean of 14 separate regions where based of the distance of each area form the source of flare and the type of activities conducted near each area which directly affect the reading of SO_2 and NO_2 for gas exploration and SO_2 and NO_2 because its p-value (0.001) is less than the significant level of $\alpha=0.05$. It means, another indirect reason of the significant differences is seasonal variation and elevation of each area there is a difference between the mean of fourteen regions for gas exploration including D pad Down Area, Shilya Road, ECP 1, Wastewater Pit Area, ABC Camp, A pad, ATOC, CPF, ECP 2, G pad, E pad, ROW, C pad, and ECP 3.

Table 6: Comparison between the mean of 14 separate regions for oil and gas exploration and production by SO_2

	N	Mean	SD	95% CI for Mean		Min	Max	F	p-value
				Lower Bound	Upper Bound				
D pad Down Area	7	14.510	5.069	9.822	19.198	9.510	24.100	13.278	0.001
Shilya Road	7	20.574	5.978	15.045	26.103	13.520	32.660		
ECP 1	7	14.810	2.400	12.591	17.029	10.330	17.790		
Waste Water Pit Area	7	18.584	2.962	15.845	21.323	12.650	22.260		
ABC Camp	7	16.033	2.753	13.487	18.579	11.570	19.450		
A pad	7	22.306	3.552	19.021	25.591	16.230	25.730		
ATOC	7	10.689	2.142	8.708	12.669	7.180	14.200		
CPF	7	26.386	3.607	23.050	29.721	21.100	31.440		
ECP 2	7	16.986	6.469	11.003	22.969	11.520	30.770		
G pad	7	16.304	6.062	10.698	21.910	10.730	29.010		
E pad	7	23.074	2.688	20.589	25.560	18.700	26.460		
ROW	7	13.369	4.341	9.354	17.383	8.320	21.680		
C pad	7	11.086	4.332	7.079	15.092	6.350	18.800		
ECP 3	7	4.373	1.655	2.842	5.903	2.390	7.150		
Total	98	16.363	6.733	15.013	17.713	2.390	32.660		

Table 7: Comparison between the mean of 14 separate regions for oil and gas exploration and production by NO_2

	N	Mean	SD	95% CI for Mean		Min	Max	F	p-value
				Lower Bound	Upper Bound				
D pad Down Area	7	6.431	1.122	5.394	7.469	4.580	7.960	3.109	0.001
Shilya Road	7	6.353	2.404	4.129	8.577	4.250	11.630		
ECP 1	7	6.100	1.551	4.666	7.534	3.060	7.820		
Waste Water Pit Area	7	5.993	1.851	4.281	7.705	2.770	8.080		
ABC Camp	7	3.854	1.868	2.127	5.582	0.300	5.750		
A pad	7	6.310	3.078	3.463	9.157	0.300	9.710		
ATOC	7	5.063	2.327	2.911	7.215	0.300	7.820		
CPF	7	5.754	2.584	3.365	8.144	0.300	8.060		
ECP 2	7	7.716	4.330	3.711	11.721	0.300	14.300		
G pad	7	7.234	3.455	4.039	10.430	0.290	10.420		
E pad	7	8.941	3.826	5.403	12.480	2.110	12.920		
ROW	7	3.579	1.289	2.387	4.771	2.520	6.240		
C pad	7	3.100	1.810	1.426	4.774	0.300	6.100		
ECP 3	7	3.089	3.121	0.202	5.975	0.030	9.400		
Total	98	5.680	2.995	5.079	6.280	0.030	14.300		

4. CONCLUSION

Passive diffusive sampling may be used to reliably measure the seasonal variability in the atmospheric Nitrogen dioxide and Sulfur dioxide levels at sample locations of different Oil and Gas operations in the region. The quantitative Sulfur dioxide and Nitrogen oxide concentrations obtained by the IC and UV-Vis techniques highest correlation. Both Nitrogen dioxide and Sulfur dioxide had a seasonal trend; for example, highest Sulfur dioxide levels were seen in February 19.01 ppb and in areas close to flares with high elevation, whereas March had seen the lowest levels 14.36 ppb. The lowest amount of Nitrogen dioxide was recorded in December 2.45 ppb at low elevation and without operating of heavy equipment, whereas the Nitrogen Dioxide peak was recorded in November 7.21 ppb at the site where heavy equipment was in operations. The passive diffusion samplers in this study presented a reliable method to examine the variations in ambient air quality along a vast region in response to different gas production operations since their overall accuracy was consistent with that observed in other studies elsewhere. In order to identify areas with increased ambient concentrations, dispersion modelling and short-term consistent monitoring should be combined with passive monitoring of Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2), as was done in the current study.

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